Iterative Assessment Cycle Powered by Teachers and AI

Hajime Shirouzu, CoREF, University of Tokyo, shirouzu@coref.u-tokyo.ac.jp
Moegi Saito, CoREF, University of Tokyo, saitomoegi@coref.u-tokyo.ac.jp
Shinya Iikubo, CoREF, University of Tokyo, iikubo@coref.u-tokyo.ac.jp
Takahiro Nakayama, CoREF, University of Tokyo, nakayama@coref.u-tokyo.ac.jp

Abstract:
Lesson improvement requires a collaborative PDCA (plan-do-check-act) cycle of teachers, but it takes too much time and effort to turn the cycle in their ordinary lives. Thus, we propose two ideas to build an "Iterative Assessment Cycle" of students' collaborative learning. The first idea is the reciprocal collaboration between humans and AI, and the second is utilizing teachers' ordinary endeavor of assessment as a resource for knowledge advancement of both humans and AI. Study 1 examines if the pre-registration of keywords into an automatic transcription system of student's dialogue would raise the speech recognition rate or not. The study showed the positive results, and revealed another issue of how to connect teachers' redesign of the lesson with pre-registration of keywords. Study 2 develops a dialogue analysis tool in the iterative assessment cycle using a shared lesson framework, and examines its effect with the case of a veteran teacher. The teacher first stuck to his own hypothesis of the lesson, but with the help of tool-assisted dialogue analysis in a teacher community, he found a hidden problem of the lesson and came up with a new plan, which eventually caused more productive dialogues among students referring to expected keywords. We discuss how to connect this kind of teacher's endeavor of lesson improvement with AI's evolution for assessment.

Keywords: iterative assessment cycle, knowledge constructive jigsaw, dialogue analysis

Introduction

Lesson improvement requires a collaborative PDCA (plan-do-check-act) cycle of teachers, but it takes too much time and effort to turn the cycle in teachers' ordinary lives. Thus, we propose two simple ideas to build an "Iterative Assessment Cycle" of students' collaborative learning: first, the reciprocal collaboration between human beings and AI, and second, utilizing teachers' ordinary endeavor of assessment as a resource for knowledge advancement of both humans and AI.

Research indicates that one-off seminars or short courses do not contribute much to teacher learning, and effective professional development involves opportunities for teacher to have actual classroom practices (Avalos, 2011; Voogt, 2010), to reflect upon their practices (Ross & Bruce, 2007), and to participate in a community of practice with peers and experts over an extended period of time for continuous improvement of practices (Penuel *et al.*, 2007). This means that the collaborative PDCA cycle holds the most important place for teachers' development. However, if teachers engage in designing student-centered lessons like knowledge building (hereafter KB), it takes much time to collect, transcribe and analyze students' conversations other than written texts on learning systems like Knowledge Forum (hereafter KF). In other words, if we can succeed in helping teachers engage in this time-consuming, but central step of PDCA cycle, the "Check" step, teachers can learn from classroom practices as well as raise the quality of practices effectively. We can also apply such a finding to the KB communities, since the "Check" step is assessment, and when the assessment becomes a concurrent, embedded and transformative assessment (Scardamalia, 2002), the PDCA cycle of the lesson becomes the assessment cycle itself.

Then, how can we help teachers *check* students' learning and the quality of lessons? We hypothesize that the other steps of Plan, Do, and Act can also serve to raise the quality of Check activity, since assessment benefits from teachers' explicit plans of what kind of learning they want to take place in the classroom and redesign of lessons in order to make such learning occur more clearly, effectively, and productively. Thus, the PDCA cycle should be turned iteratively in the way that the assessment improves its quality. We represent such a cycle in Figure 1a, which has a teachers' collaborative PDCA cycle of lesson improvement in its inner circle. We call this cycle an iterative assessment cycle, since we can equate teaching with assessment by the reason above. Support systems on the outer circle (Figure 1a: pale green and blue shadow boxes) help teachers to turn the cycle in a timely manner. In addition, as teachers use these systems to plan, discuss, conduct, reflect upon, and share about the lessons iteratively, the system including AI gets smarter.

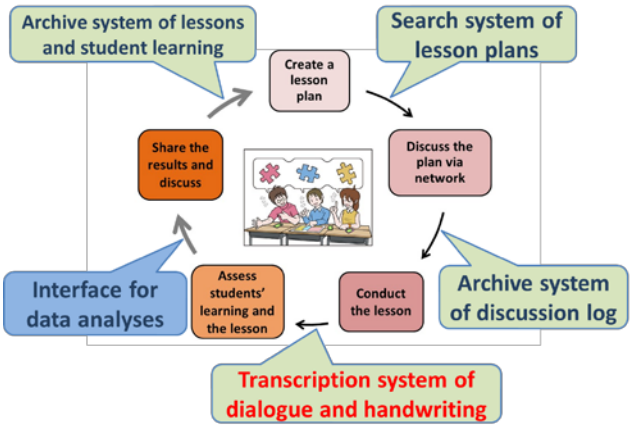

Figure 1a. Iterative assessment cycle and support system

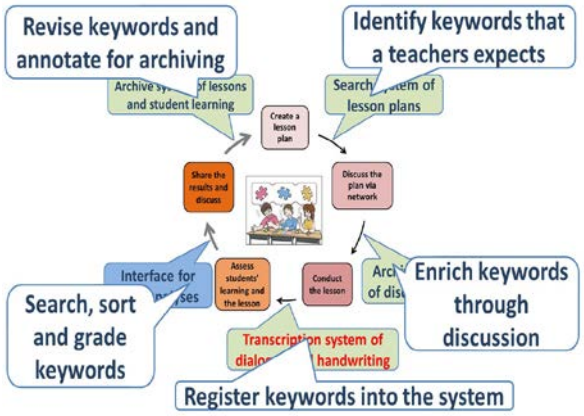

Figure 1b. How the cycle and system works in the case of keyword detection

For example, Figure 1b shows how such collaboration between humans and AI contributes to their co-evolution. When a teacher creates a lesson plan, s/he expects keywords that students refer to or write in the lesson according to her or his own goal of the day. Several teachers can simulate this lesson plan from multiple perspectives including a student-centered perspective, and enrich a variety of keywords. On conducting the lesson, however, the teachers often find that students' expression of core ideas are more diverse than expected. In assessing student learning, the teachers put keywords into the analytic tool, learn how students use, share and improve their keywords, and sort and grade them according to her or his newly-created criterion. The teachers feed the results back to the archive system with their reflection. Very importantly, when another teacher tries to conduct the similar lesson, s/he can have enriched database of students' actual written and dialogue data. If s/he can register appropriate keywords into the transcription system, the speech recognition rate gets higher, which is the most difficult parts of dialogue analysis (red letter in the pale blue box of Figure 1a). In a series of research, our group would like to examine if such kind of speech-to-text translation can promote in-depth analyses of collaborative learning by researchers, high-quality lesson improvements by teachers, and context-driven approaches to semantic analyses of learning by engineers.

But how? The scheme described above might sound plausible, but how can we create a community wherein teachers "not only share ideas but generate and refine new ideas through the dynamics of networked social interaction" (Scardamalia *et al.*, 2017)? So, we have introduced constraints of an instructional and assessment framework of lesson as a simple but strong core of constructive interactions among all (Miyake, 2013; Shirouzu *et al.*, 2016). Specifically, this study builds on a Japanese learning sciences project by the Consortium for Renovating Education of the Future (hereafter CoREF; http://coref.u-tokyo.ac.jp/) of the University of Tokyo, which utilizing a concrete lesson framework, "Knowledge Constructive Jigsaw" method (hereafter KCJ: depicted in its center of Figure 1a), has seen the teaching of approximately 2,000 lessons every year by teachers of all subjects across all grades from 1st to 12th, supported by 30 regional boards of education. The participating teachers, experienced as well as novice teachers, work together to design, practice and reflect lessons across subjects, schools and districts, either face-to-face or via the internet. Using this set of a common method and learning community around it, teachers can obtain "streamlined" data, reflect upon it collaboratively, and become "annotators" by using the system that we propose. Yet, we do not want to propose that the KCJ is the only way to do this, but want to provide with a set of constraints spanning across multi levels in which this kind of cycle can be turned anyway in a "quicker and dirtier way" (Miyake, 2013).

Hereafter, we first illustrate the KCJ method. Then, we examine if the pre-registration of keywords into an automatic transcription system of student's dialogue would raise the speech recognition rate in Study 1. In other words, this study examines the effect of "P (plan)" on raising the quality of data for "C (check)" in the PDCA cycle. In Study 2, we develop a dialogue analysis tool embedded in the iterative assessment cycle using KCJ, and examines its effect with the case of a veteran teacher who turned the PDCA cycle twice. This study thus examines the effect of double loops of the PDCA cycle on raising the quality of "C" step.

Framework of the Knowledge Constructive Jigsaw (KCJ)

The KCJ consists of five learning activities: (1) writing an answer to the day's given problem based on a rule of thumb, (2) an expert-group activity which allows each individual student to accumulate some pieces of knowledge relevant in solving the problem, (3) a jigsaw-type activity where students from different expert

groups get together to exchange and integrate the accumulated pieces of relevant knowledge and form an answer, (4) a cross talk activity where the students exchange their ideas for solutions, involving the entire class, and (5) writing down an individual answer again to the same problem and newer questions. Compared with the original Jigsaw method (Aronson, 1978), this method emphasizes the role of a shared "problem" for knowledge construction. Although strongly scripted, this method is dynamically adaptable to any learning contents and situations in the sense that each teacher can decide the "problem (jigsaw task)" and "learning materials (for the expert activity)." The essential flow of activity allows *constructive interaction* (Miyake, 2013) among task-doers and monitors to take place naturally and repeatedly: the design requires each student to become a *task-doer* in the jigsaw group, and provides each student with the chance to become a *monitor* who infers what the other students say and why they say that, in order to integrate the ideas of others with their own.

From perspectives of data analysis and engineering, this method has two features. First, since it lets students write down their answers to the same question twice, that is, at the beginning of the lesson and its end, the change or improvement between two answers give hints to infer what kind of interaction including dialogue takes place during two time points. Second, since students externalize their ideas or prior knowledge at step (1) above, intake information from reading and discussion on the material as well as verbalize their ideas at step (2), exchange and integrate ideas at step (3), present her or his group's ideas and listen to the other groups' ideas at step (4), and finally externalize their ideas and next question ("What I Need to Know") at step (5), we can detect information source and flow that crystalizes into each student's final understanding of the day.

Study 1

We are now developing a whole set of the systems, and report here only a part of it: an automatic transcription system of student's dialogue. The work is still in progress, and thus let us report its preliminary results briefly.

Method

System

The system consisted of unidirectional microphones attached to each student, and automatic transcription tools with a cloud engine. This engine accepts pre-registration of keywords by user up to one hundred words. Using this system, we iterated high-school Japanese lessons for four times.

Participants and Instructional Procedure

Each fifteen high-school students and/or prep school students participated in the lesson, totaling up to sixty. The lesson let students deepen their understanding of a short story, a Japanese novel "The bag (Kaban)" by Kōbō Abe, through the KCJ method. Students first read the story to think what the main message the story tells, and then were divided into three groups, one of which considered how the main character feels and changes his thought as story develops, another of which reflected how another character does so, and the other of which thought of meanings of two expressions found in the novel. Each three members from different groups formed one jigsaw group to think again about the message of the story, reported their thoughts to the class and wrote down their answers individually at the end.

Measures and Technological Procedure

Through first three iterations, we got the accuracy rate of automatically transcribed data compared with the whole truth transcription, that is, 100% minus WER (the word error rate), of about 23% to 36% depending on groups at the step (3) of the jigsaw activity. The reason why the rate differed greatly by groups is that the acoustic and language models were not adjusted to particular groups, where group members simultaneously talk, take over each other's utterance, and sometimes suddenly burst into laughing.

Thus, we focused on transcribing the crosstalk at the step (4), where a representative of each group presents their final answer in turn and the other groups quietly listen to that. Yet, they use many colloquial expressions instead of formal ones found in the material (the novel in this class), and thus we need an extra "dictionary" produced by their own conversations and writings. During three iterations, we gained the conversation data of a total of a hundred thousand Japanese characters (roughly corresponding to thirty to fifty thousand English words), which were classified into about two thousand "different" (Japanese) words. We, the researchers, chose 49 hot words from them, register the words into the system beforehand, and applied the system to the crosstalk at step (4) of the fourth (final) trial of the lesson.

Results

Table 1 represents the result. The "recognition rate" represents the accuracy of the words transcribed by the system, while the "recognition accuracy" means the accuracy of the transcribed compared with the whole truth transcription. Pre-registration of keywords resulted in an accuracy gain of about 10%, since the recognition of the registered words (often hard-to-recognize words, without registration) contributed to that gain. Still, the rates are still too low to use them online by teachers. We need more words to register and need to know how to choose words to raise rates.

Table 1: The accuracy rate of transcription system with or without pre-registration of keywords

	Recognition rate	Recognition accuracy	Recognition rate of registered words
Third trial of the lesson	66.7% (SD: 16.9%)	58.2% (SD: 20.2%)	---
Fourth trial of the lesson	74.0% (SD: ---)	64.4% (SD: 5.8%)	63.5% (varied from 0 to 100%)

Study 2

Study 2 demonstrates the effect of a keyword-detecting tool of students' dialogues for a teacher's "reflection on action" (Schön, 1987) when properly embedded in a collaborative PDCA cycle of lesson improvement. In the knowledge society, teachers should improve their lessons continuously for students' better knowledge construction. As "reflective practitioners" (Schön, 1987), teachers should not only be able to implement researchers' advice for improvement but also be able to find problems in their lessons, propose plausible solutions and implement them by themselves. Students' dialogues are precious resources for such reflection as analyzing students' learning processes, evaluating the lesson and planning the next one. Thus, even with a simple dialogue analysis tool, if we properly embed it in a PDCA cycle of improvement, we can contribute to making a difference in the quality of students' learning by prioritizing teachers' equity and access in CSCL.

In the field of Learning Analytics, it becomes important to best make information on students' learning processes accessible and useful to teachers, *or* to design an analytic tool from a "teacher-centered" perspective (Erkens *et al*., 2016; Matuk, Cocco & Linn, 2016). Although there have been many conversation analysis tools in the field of CSCL, such as KBDeX (Oshima, Oshima & Matsuzawa, 2012), PolyCAFe (Trausan-Mau, 2013), and Tatiana (Dyke, Lund & Girardot, 2009), most of them are best used by researchers who have enough time to dig through the process data of different situations to yield generalizable analytic methods and findings. Instead of applying such methods to the automatization of analysis and recommending analytic results of high quality to teachers, our focus is on 1) raising the quality of the teacher's own "process of analyses" and 2) providing teachers with a PDCA cycle to "use" their analytic results for lesson improvements, since we assume that such experiences will have the effect of raising the quality of teachers' reflection and selection of keywords. In order to put this objective into practice, we need a common instructional framework for teachers to interpret and discuss the data of students' learning processes in a meaningful way, by introducing the KCJ method.

Method

Dialogue analysis tool

We have developed two assessment tools utilizing observation chances in the KCJ format that enable "visualization" of the students' learning processes. The first tool is "a comparison of pre- and post-class comprehension," which simply asks the same question twice in the steps (1) and (5) above. Thanks to this, children can compare their own answers, and confirm whether they have seen progress. Teachers can also compare the answers with their expectations, and ascertain to what extent children have deepened their understanding and how diverse their expressions are. The second tool is "multilateral dialogue analysis," which aims to auto-transcribe the students' conversations in all of the groups during the class and provide transcripts electronically searchable by keywords. This paper focuses on the latter tool.

This tool supports an analysis of transcription after the lesson. It has two simple functions: one function is highlighting utterances that include keywords of the lesson, and the other is changing the scope of analysis. The tool has one window for analyzing one group dialogue carefully (Figure 2a), which represents each student in each column and each utterance in each cell. If a user enters a keyword in a colored area, then the cell including the keyword turns into a colored cell. The other window is for comparing dialogues of all groups (Figure 2b), which shows each student in each column and each utterance in just one line. Thus the user cannot see the contents of the utterances, but is able to grasp an overall image of the distribution of keywords. The user

can change these two views by clicking on any part. By using these functions, teachers can both analyze whether and how each student discusses the topic in the expert or jigsaw group using keywords related to the lesson contents or social processes, and examine to what extent a found pattern is universal among the groups.

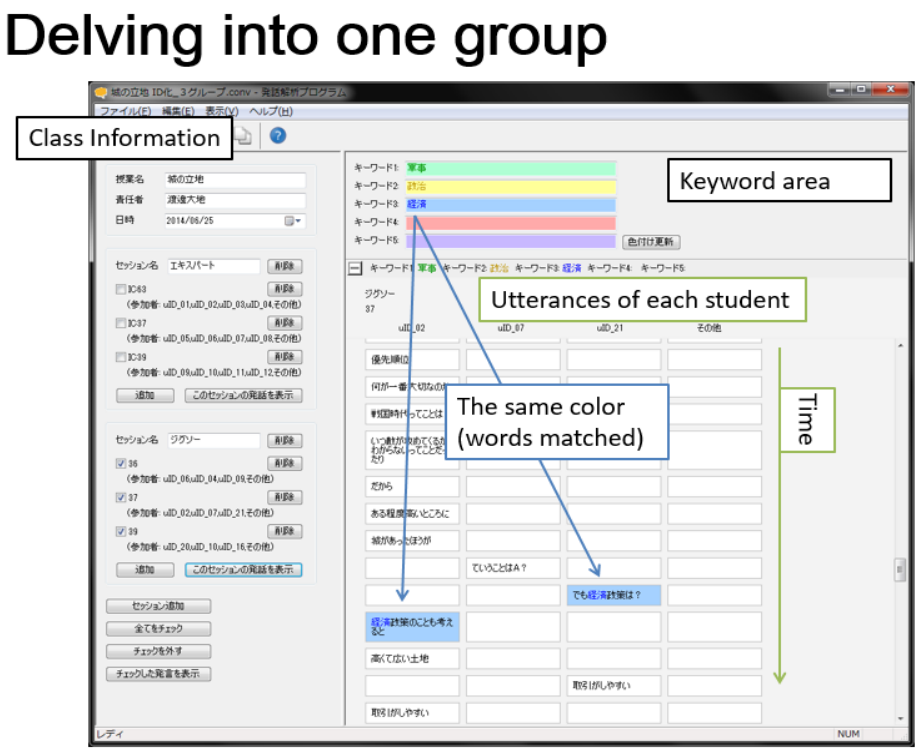

Figure 2a. The dialogue analysis tool: Close-up window

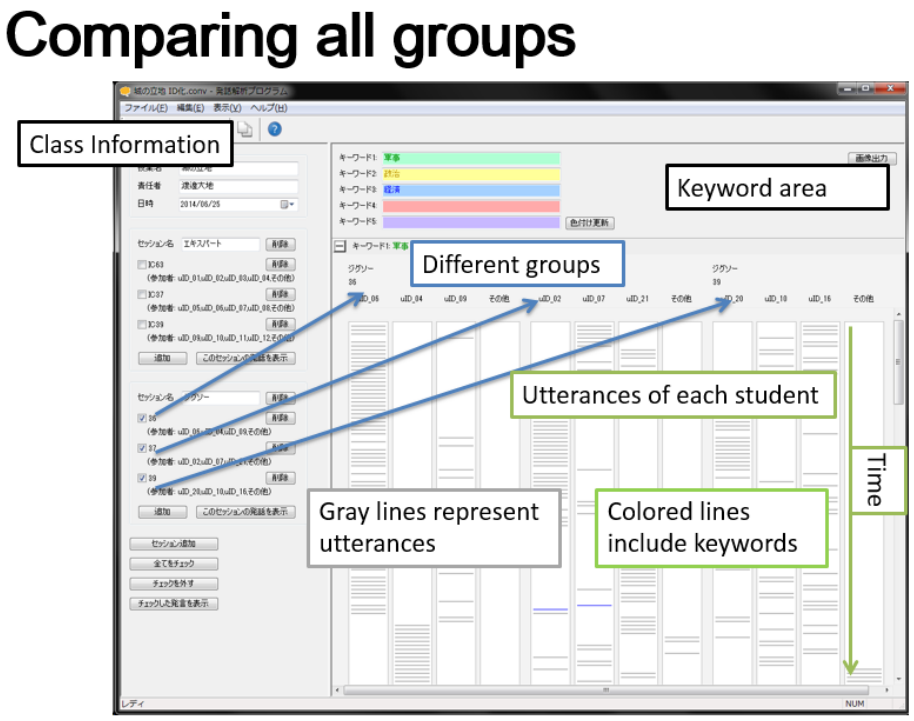

Figure 2b. Bird's-eye window

Research Setting and Teacher K

As shown in Table 2, this study focused on Teacher K's lesson improvement process spanning over the three-year period from the year 2014 to 2016, using the above dialogue analysis tool in a seminar described below in the year 2015. Since this research was conducted using a case study method, we will be giving its details together in the Results section.

The teacher (hereafter "Teacher K") who was the subject of this study is a junior-high school, male teacher. He has been working as a science teacher for 28 years and has taught at seven junior-high schools in several cities and towns of a rural prefecture over his teaching career. He participated in the CoREF project from its initial stage, the year 2008, having developed more than thirty KCJ lesson materials. He has not only attended CoREF's teacher training workshops more than 30 times, but has also served on five occasions as a lecturer in these workshops and symposiums. He also participated in a seminar called "KCJ and Lesson Study Masters" in the year 2014, which saw 40 teachers taking part from all around Japan, providing them with more advanced contents of learning sciences, enabling the teachers to connect them with their own KCJ experiences, and also to discuss their learning sciences. As a master teacher, he not only opened his classes up to other teachers, but also traveled to other districts in order to conduct KCJ lessons in other teachers' classes.

Results

Teacher K taught a science lesson to 8th graders using the KCJ method on a unit of the mechanics of human body movements in the year 2014, and reflected on the lesson directly after teaching it, especially on the gap between what he had asked the students to do and what the students understood to be "today's task." By analyzing the students' dialogues in a seminar about a year later, however, he became aware of the difficulties students faced in extracting and integrating the information from the expert materials as well as the need to describe the task more clearly. After a further year, when given the chance to try teaching the unit again, he revised his lesson plan, which ultimately led to deeper understanding on the part of the students. Table 2 summarizes the whole process.

Table 2: Teacher K's lesson improvement

Phase	Event (Planning, implementing, reflecting and re-planning of the lesson)
1	**Planning of the first version of the lesson (30th June – 2nd July, 2014; on CoREF's mailing list)** Teacher K first intended to make students more conscious of their body movements in their club activities or in their everyday lives. Therefore, he planned to show a video of a person hitting a tennis ball and to have the students explain the body movements of the player, handed out three expert materials of the "nervous system," "skeletal structure" and "mechanism of muscles" and formed jigsaw groups by student club to allow the students to apply what they had learned in their activities. To this plan, one researcher expressed the concern that the task seemed too difficult for students in spite of the attractiveness of "solving personal problems." Teacher K, however, did not follow this advice and took the risk of implementing his own initial idea.
2	**Implementing the lesson and reviewing it in a meeting (4th July, 2014)** The lesson went over the allotted time since students had difficulty in integrating the information in the jigsaw groups and presenting it in the crosstalk. Directly after the lesson, Teacher K said in the meeting, "The children did not seem to be conscious of their own movements, so I should have used the video or whatever to enable them to think deeply about the inside workings of their bodies," which implied Teacher K had found some problems with his lesson but had just resorted to another know-how of teaching.
3	**Reviewing the lesson in a CoREF reflection sheet (July, 2014)** In the CoREF reflection sheet, the teacher is requested to select any three students and compare their pre and post class answers. Teacher K reflected upon these answers and the overall impression of the class, writing "Although even in bending one's arm, "*the biceps brachii muscle contracts while the triceps brachii muscle relaxes*," the students' descriptions were too obscure to reach this level. This kind of goal demanded too much from the students because I did not have a clear image of what I had wanted from them. In redesigning the lesson, I would present the same movement to everybody regardless of the club the student belongs to." It suggests that he reached the idea of making the task clearer, a prototype of the next lesson.
4	**Reviewing students' dialogues of the lesson in the CoREF seminar (1st August, 2015)** About one year later from the lesson, we held a three-hour workshop in the "KCJ and Lesson Study Masters" seminar, utilizing hand-transcribed dialogues from Teacher K's lesson as described above.

	Fifty-three teachers including Teacher K himself used the dialogue analysis tool collaboratively to dig through one to three jigsaw groups of students. Before using the tool, Teacher K had planned to model students' learning from "understanding of the task" and "externalizing one's own initial thoughts" through "reacting to others' thoughts (keywords of "*I see*", "*Why?*", "*Uh?*", "*Aha*")" to "restructuring one's own thoughts." During actual use, a group including Teacher K entered a keyword "*In a word*," but found that 8th graders did not use such a formal expression, and became to focus more on content words like "*ball*." After hearing other groups' findings, Teacher K wrote down not only communicative words like "*For example*" or "*Why?*" but also content words integrating three expert materials like "*command*", "*transmission*", "*reaction*" as promising keywords. Teacher K's change implies that even though he had assumed the content was not so difficult for his students, he found it was not the case. Actually, it was difficult for the students to discuss the materials with using and connecting the content keywords as he had expected.
5	**Planning of the second version of the lesson and its implementation (18th October, 2016)** When Teacher K was given the chance to teach the same unit and open that class, he decided try the KCJ lesson again. Although he changed the expert materials only slightly, he drastically changed an aim of lesson and a main task. He dropped the aim of "explaining everyday body movement" from the expected outcomes, and clarified the task by asking "What are you doing to catch a falling ruler?" and making it a common target for students to explain. He also clarified the expected outcomes such as "Students should explain "*I get a stimulus that the ruler starts to move from the eyes. The stimulus is transmitted from the optic nerve through the sensory nerve and the spinal cord to the brain. Then the brain commands the muscles inside the thumb and forefinger to contract, the command of which is transmitted from the brain through the spinal cord and the motor nerve to the muscles inside the fingers, and the fingers successfully catch the ruler*."" By implementing this plan, almost all the jigsaw groups of students reached the answer (expected outcomes) and furthermore they tried to connect their learning outcomes to their everyday activities, what Teacher K originally wanted two years ago.
6	**Reviewing the lesson in a CoREF reflection sheet (October, 2016)** Teacher K wrote in the reflection sheet, "I felt that most of the students clearly understood the mechanics of body movement, due to the change of the task which dealt with a simple behavior. I realized that even though I changed the expert materials a little, the reaction of the students drastically changed with revision of the task and targeted material, at which I am surprised."

Teacher K first stuck to his own hypothesis of the lesson. Thanks to the PDCA cycle supported by the KCJ method and its learning community, Teacher K had been exposed to the other's hypothesis (researcher's concern) about the lesson and found "some" problems in his lesson. Yet, with the help of tool-assisted dialogue analysis in the community, he first realized the hidden problem of the lesson and came up with a newer plan. The dialogue analytics embedded in the collaborative PDCA cycle could promote teachers' own action research.

General Discussion

We examine the effect of pre-registration of keywords, that is, specification of "P (plan)," on raising the quality of data for "C (check)" in the PDCA cycle in Study 1, and the effect of turning the cycle twice on raising the quality of "C-step" in Study 2. If we can raise such quality, the PDCA cycle turns into the iterative assessment cycle.

Combining the results of Study 1 and Study 2, we found interesting results on the possibility of recruiting teachers as "annotators" of the iterative assessment cycle. First, although even a master teacher tends to reflect upon their lesson subjectively without records of learning processes, s/he can reflect upon it precisely and concretely with a just simple tool we developed here. Second, the keywords that the teacher inputs can change as her or his understanding of the lesson topic and students develops like the keywords Teacher K considered in Study 2 (italics in Table 2). Third, when the teacher deepens their understanding of the topic and how the students learn, s/he gets clearer in what kind of keywords s/he wants and gets better in re-designing the lesson, which results in gaining a higher rate of recognition of students' keywords, while the students feel freely to talk with their colloquial expressions in a more focused lesson. Such a reciprocal collaboration between systems and humans can contribute to enriching the iterative assessment cycle.

The KB community has already developed various analytic tools not only for researchers but also for teachers and even students (Scardamalia, M. *et al*., 2017), into which our research brings a perspective that sees an intertwined cycle of teaching and assessment as an arena for mutual growth of humans and AI.

Acknowledgements

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